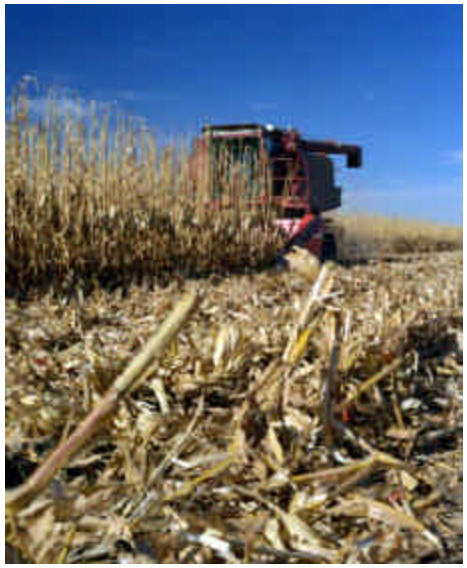


Is bioethanol sustainable?

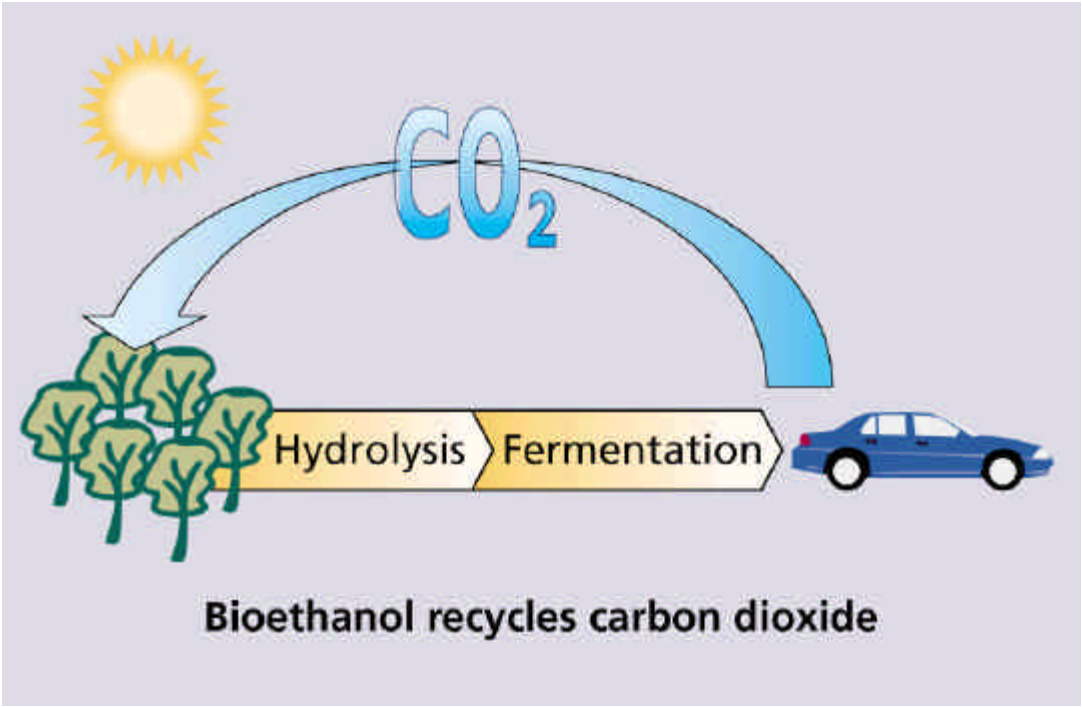
John Sheehan
Biotechnology Center for
Fuels and Chemicals
National Renewable Energy Laboratory

April 10, 2001
Ethanol Alkylates Workshop
Oakland, California

Outline

- What is bioethanol?
- Sustainability
  - a goal or a direction?
  - a framework for choosing among risks
  - Life cycle analysis and a systems approach
- Bioethanol and Sustainability
  - Resources impacts
  - Economics—cost and impact
  - The environment
  - Technology risk and availability
- Dialogue

What is bioethanol?



- Fuel ethanol made from non food biomass sources
- Requires “new” technology:
  - To break down (hydrolyze) cellulose and hemicellulose to sugar
  - To ferment unusual sugars

Sustainability—a goal or a direction?

"Sustainable (adj.) capable of being sustained or maintained"

Webster's New Twentieth Century Dictionary

Sustainability—a goal or a direction?

- From Webster's point of view, understanding sustainable development should be simple
- In practice, it is not
- Underlying this simple concept are some difficult questions. To name a few:
  - *What* should be maintained?
  - *At what cost* should we maintain "it"?
  - *Why* should we maintain "it"?
  - *For how long* should we maintain "it"?

Sustainability—a politically correct goal

"[S]ustainable development meets the needs of the present without compromising the needs of the future generations."

Our Common Future. United Nations' World Commission on Environment and Development (1987)

Sustainable development—an unattainable utopian goal

"...the great question is now at issue, whether man shall henceforth start forwards with accelerated velocity towards illimitable, and hitherto unconceived improvement; or be condemned to a perpetual oscillation between happiness and misery, and after every effort remain still at an immeasurable distance from the wished-for goal."

Thomas Malthus
An Essay on the Principle of Population (1798)

Sustainability—a way of life and an ethos

"The common aim must be to expand resources and improve quality of life for as many people as heedless population growth forces upon Earth, and do it with minimal prosthetic dependence. That, in essence is the ethic of sustainable development."

E.O. Wilson in
Consilience: The Unity of Knowledge (1998)

Sustainability—a framework for making choices

- Gloomy tone aside, Wilson's view of sustainability offers several key terms:
  - "Expanding Resources"—stewardship of natural resources, both renewable and nonrenewable
  - "Quality of life"—economic and moral attributes of a "good life"
  - "Earth"—the environment we live in
  - "Minimal prosthetic dependence"—a balanced role for technology and technological risk
  - "Ethic"—the political values of our community and the moral values of individuals

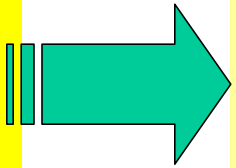
Sustainability—a framework for making choices

"[Sustainable agriculture] has all the makings of an ideal concept that requires a holistic, integrated, interdisciplinary, or systems-oriented approach that can be talked about but not easily translated into practical research."

Rattan Lal, in preface to *Soil Management for Sustainability* (1991)

Talking about sustainability

- "Systems oriented"
- "Expanding Resources"
- "Quality of Life"
- "Earth"
- "Minimal prosthetic dependence"
- "Ethic"



- Life Cycle
- Renewable Resources
- Economics
- Environment
- Technology risks
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Bioethanol and sustainability

- "Systems oriented"
- "Expanding Resources"
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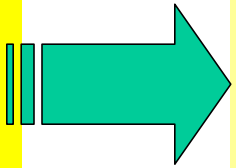

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Life Cycle Assessment—a framework for making choices that support a sustainable society

- A “comprehensive” accounting of a product’s flows to and from the environment
  - Air, water and solid waste emissions
  - Energy resources
  - Other primary resources extracted from the environment
- “Cradle to grave”

Sustainability: the life cycle of fuels

Energy Crop, Waste, Residue

Biomass Transport

Hydrolysis and Fermentation

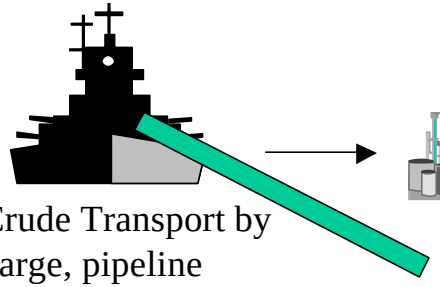
Ethanol

One Mile Traveled

Feedstock Production

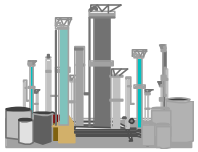
Crude Oil Production

Feedstock Transport



Crude Transport by barge, pipeline

Feedstock Conversion



Oil Refining to Gasoline

Fuel Distribution

Reformulated Gasoline

Bioethanol and sustainability

- "Systems oriented"
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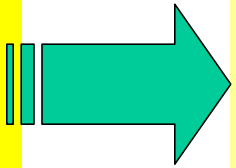

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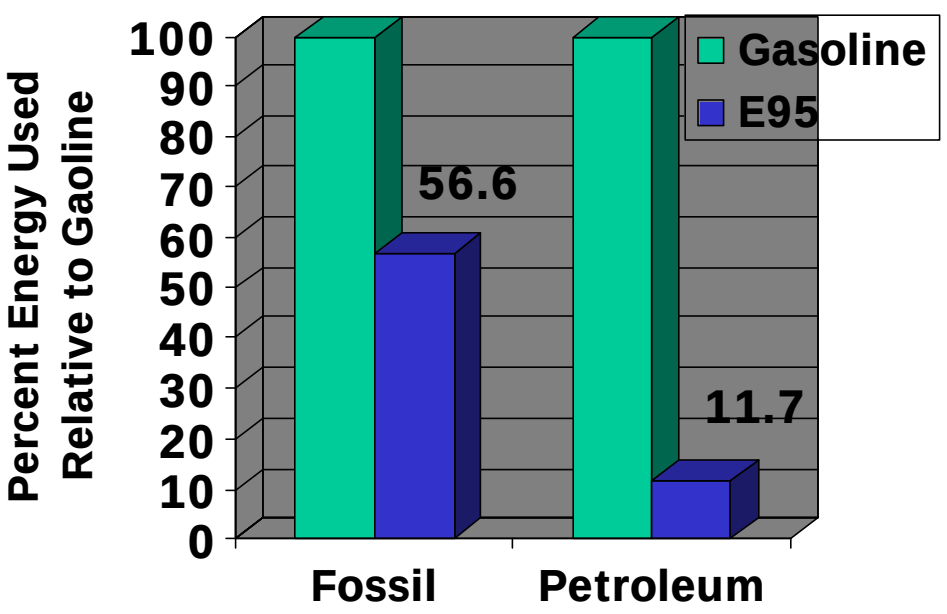
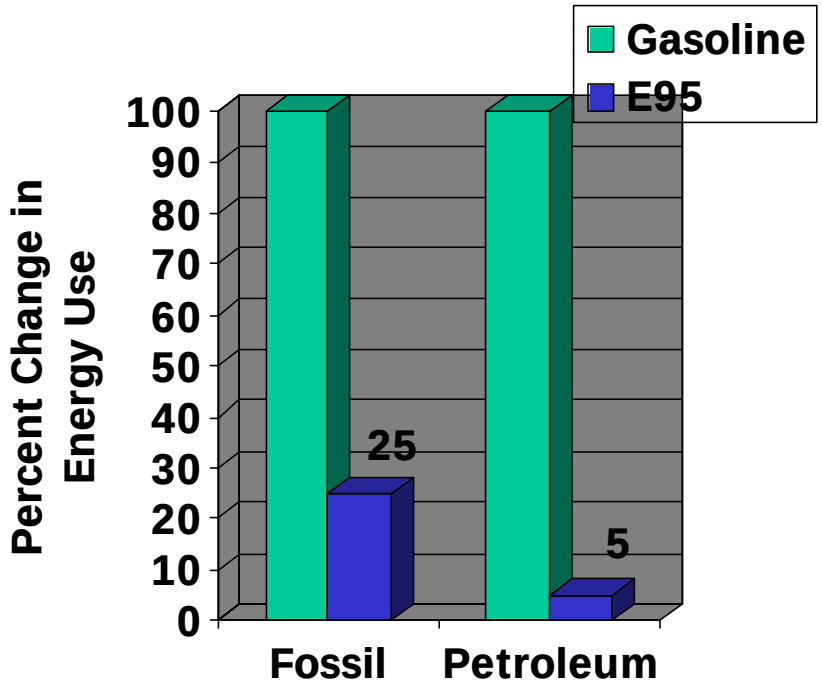
Resources: Life cycle energy use for corn ethanol

- Despite many early reports to the contrary, corn ethanol moves us in the right direction in terms of sustainability
- 43% drop in fossil energy use relative to gasoline
- 88% drop in petroleum use



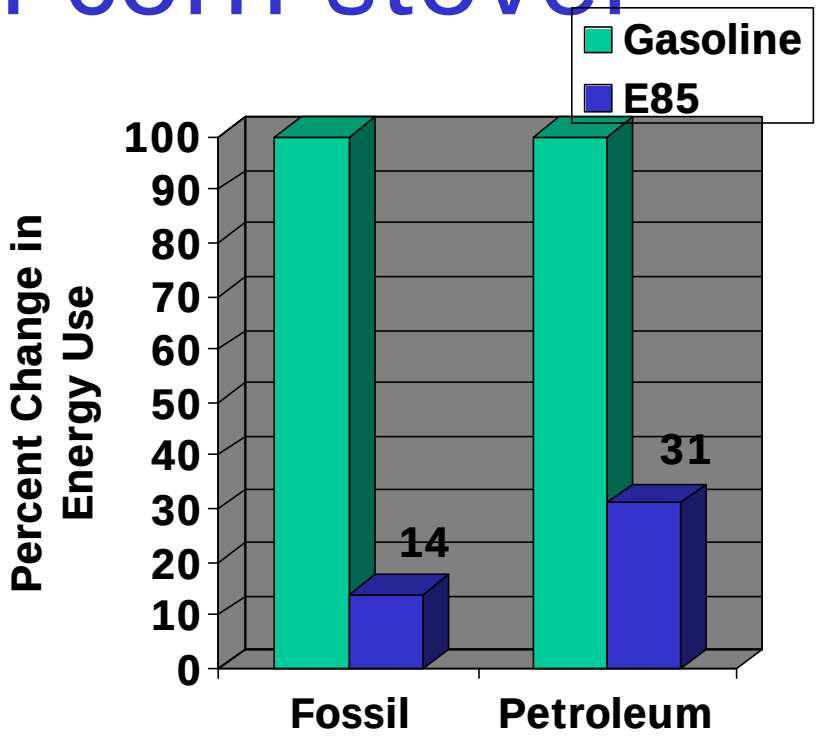
Resources: Life cycle energy use for bioethanol from energy crops

- Energy crops look even better in terms of sustainability
- 75% drop in fossil energy inputs relative to gasoline
- 95% drop in petroleum use



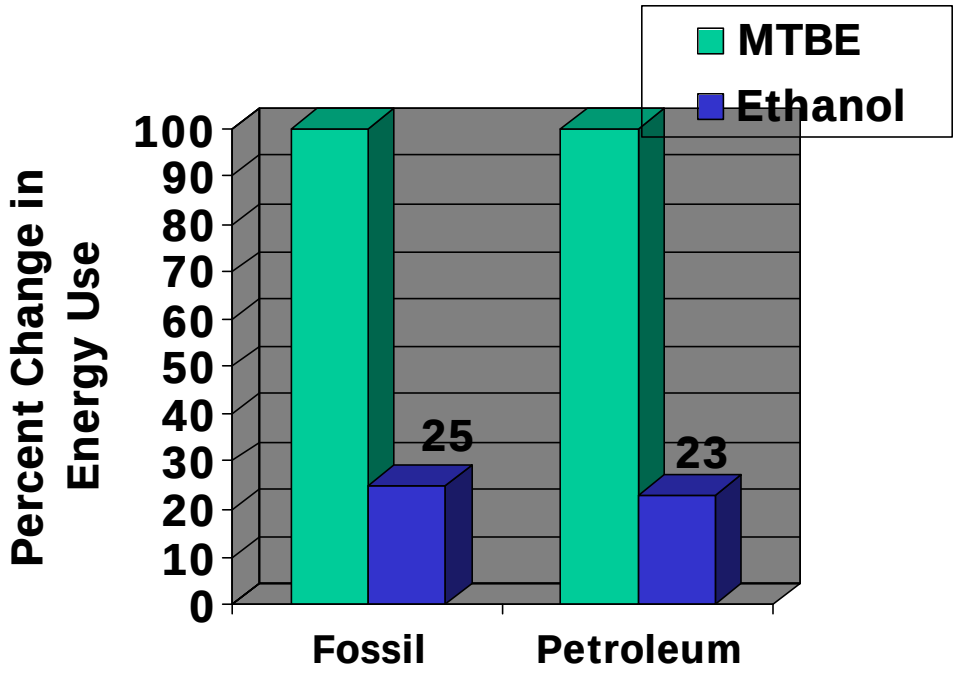
Resources:
Life cycle energy use for bioethanol from corn stover

- Residues from corn harvests are attractive as mid term energy supplies
- 86% drop in fossil energy inputs relative to gasoline
- 69% drop in petroleum use



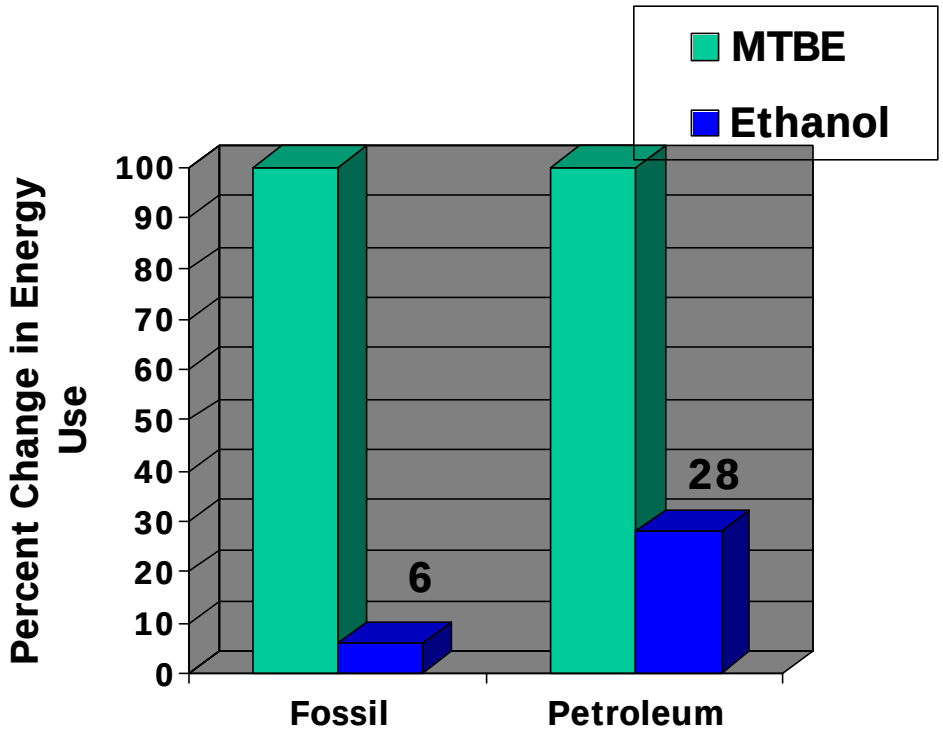
Resources: Life cycle energy use for rice straw in CA

- Making ethanol is a more sustainable alternative to open burning of rice straw
- 75% drop in fossil inputs relative to MTBE
- 77% drop in petroleum inputs relative to MTBE



Resources: Life cycle energy use for forest residue ethanol in CA

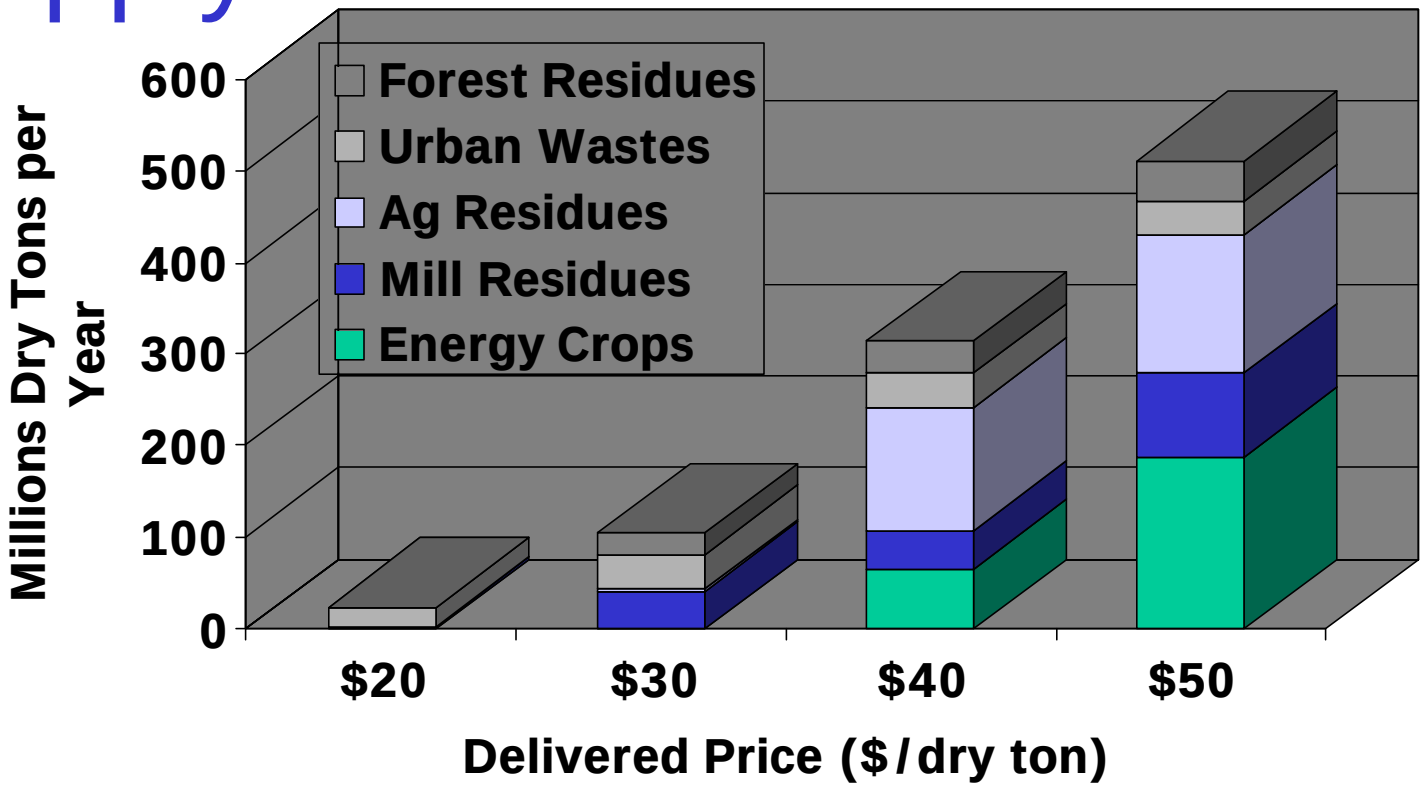
- Making ethanol is a more sustainable alternative to controlled burning in forests
- 94% drop in fossil energy inputs relative to MTBE
- 72% drop in petroleum inputs



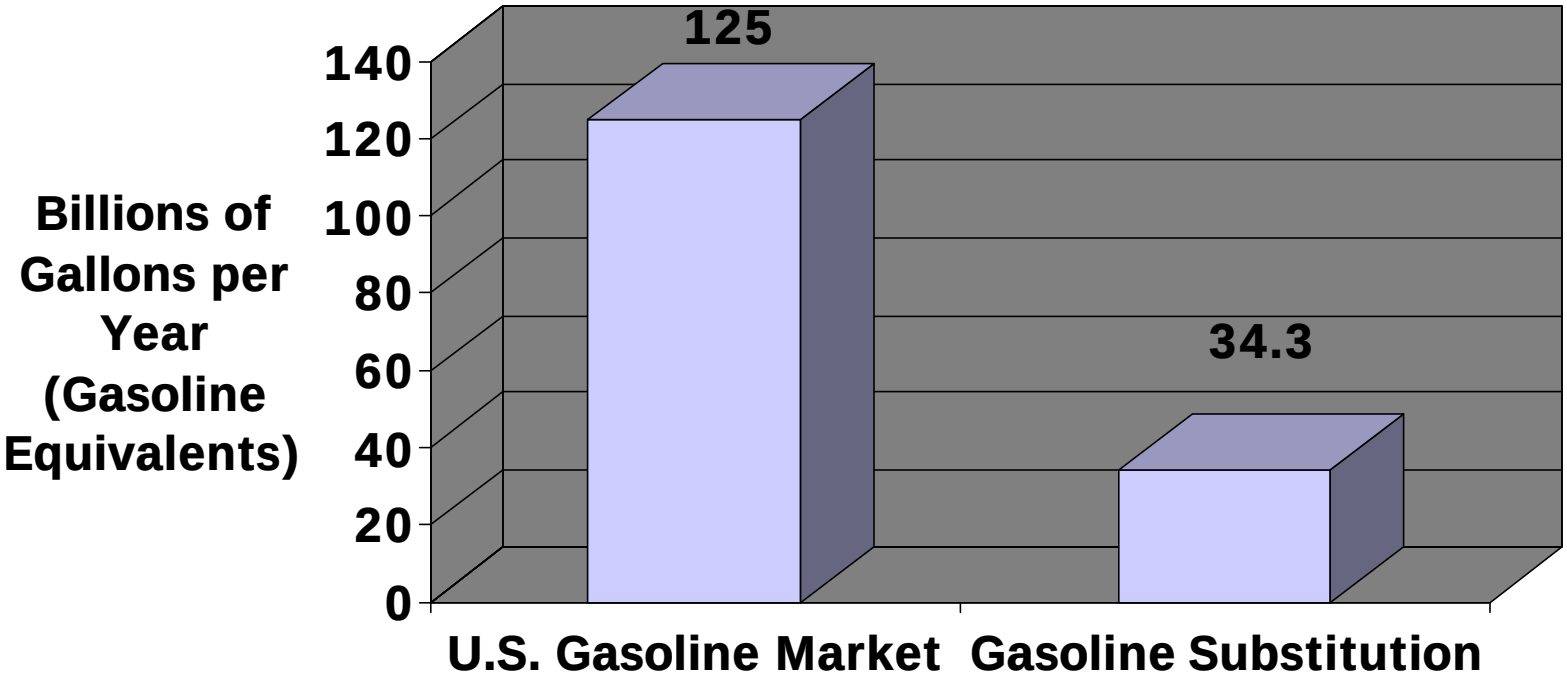
Resources: Can bioethanol make a difference?

- Joint study by U.S. Department of Agriculture and U.S. Department of Energy to estimate future production of grasses and trees as dedicated energy crops
- 42 million acres (10% of total cropland) could switch to bioenergy crops
- Includes 13 million acres of Conservation Reserve Program (CRP) land
- 181 million dry tons of switchgrass per year at $50 per ton or less.

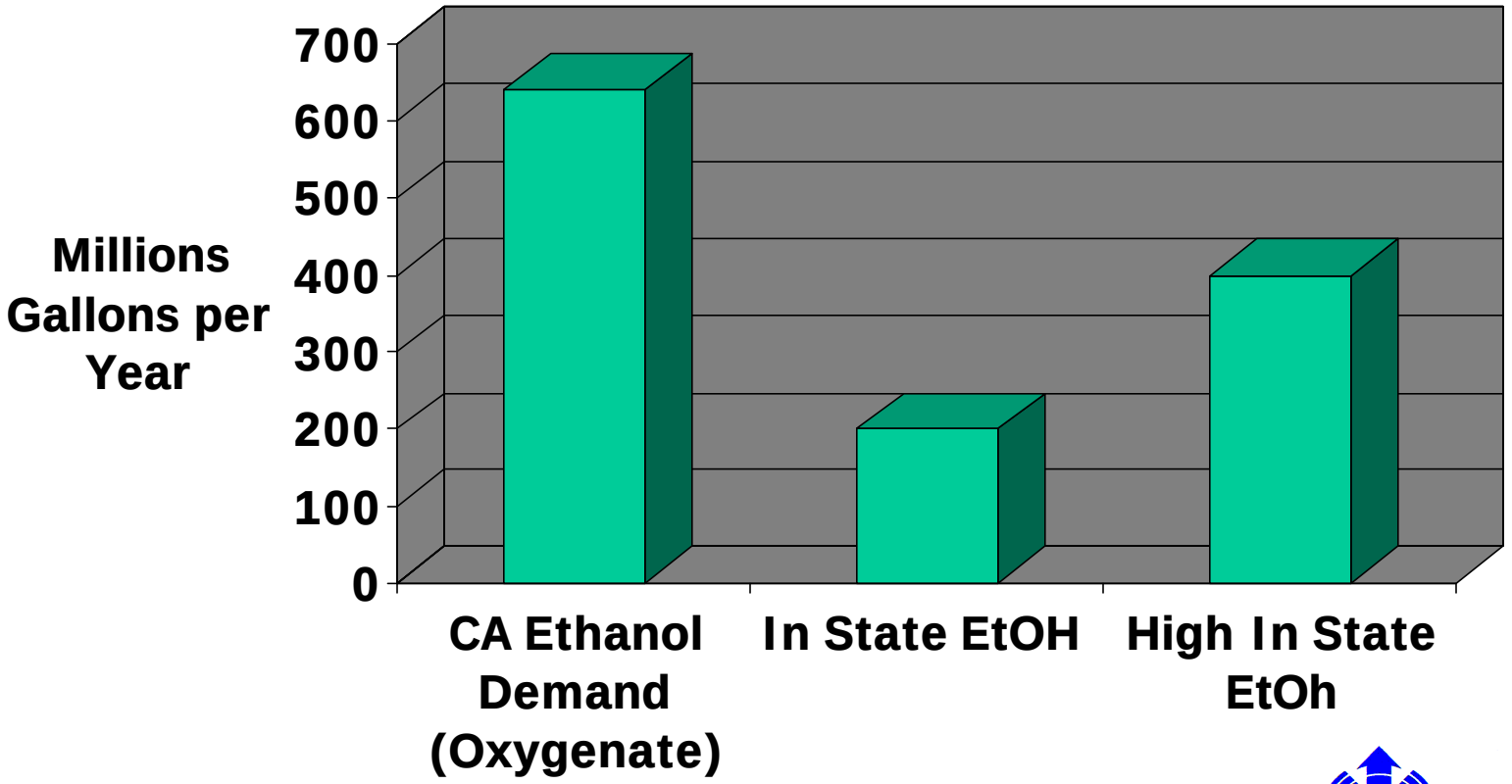
Resources: Potential U.S. Biomass Supply



Resources: Maximum Impact of Bioethanol on U.S. Gasoline

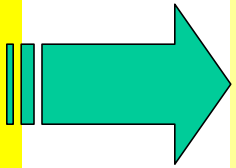


Resources: Maximum Impact of Bioethanol on CA Gasoline



Bioethanol and sustainability

- "Systems oriented"
- "Expanding Resources"
- "Quality of Life"
- "Earth"
- "Minimal prosthetic dependence"
- "Ethic"



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Economics: A new industry for California and the U.S.

- The CEC's recent findings on ethanol
  - "The benefits of biomass-to-ethanol...for California's economy are potentially greater than the cost of state support for such an industry"
  - $1 billion in economic benefits from $500 million in incentives for a 200 million gallon industry in CA
    - Includes benefits across the life cycle

Bioethanol and sustainability

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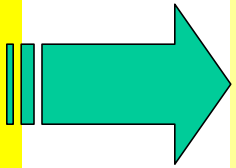

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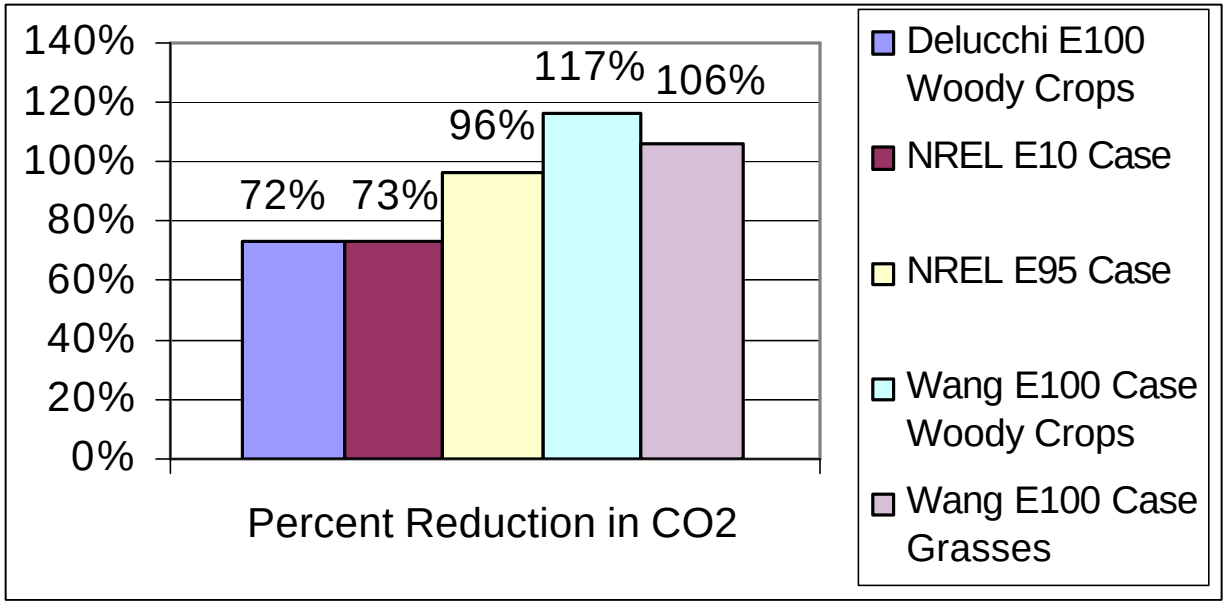
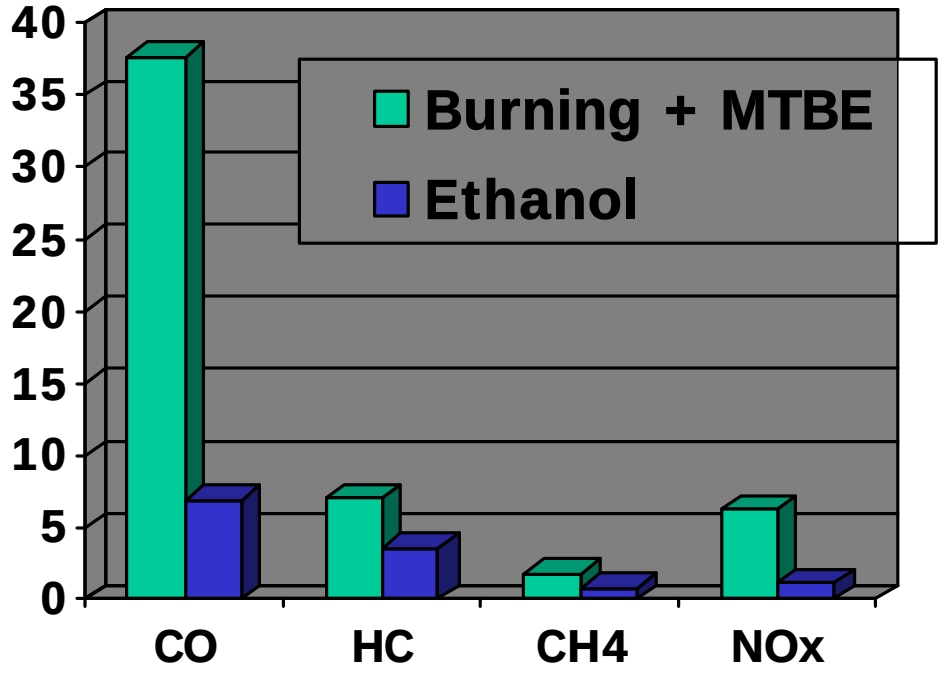
Environment: Climate change as a case study in sustainability

- The fossil energy benefits of bioethanol translate directly into greenhouse gas reductions



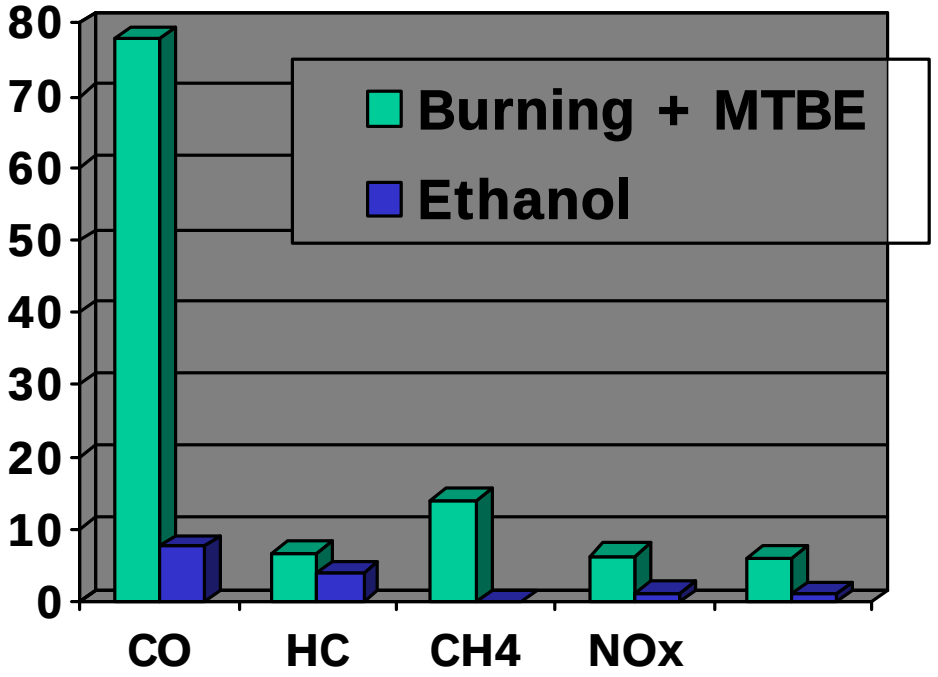
Environment:
A holistic approach leads to multiple benefits

- Avoided emissions from open burning of rice straw



Environment: A holistic approach leads to multiple benefits

- Avoided emissions from controlled burning to remove excess fuel in forests



Environment: The risks of genetically engineered organisms

- The “inside/out” view
  - While the use of genetically engineered organisms does carry with it some risk, we focus on the use of GMOs *only* in the process operation
  - As we learn more, we may explore genetically modified crops as well, but this is in the future

Bioethanol and sustainability

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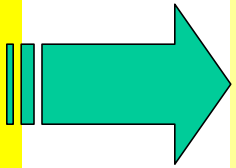

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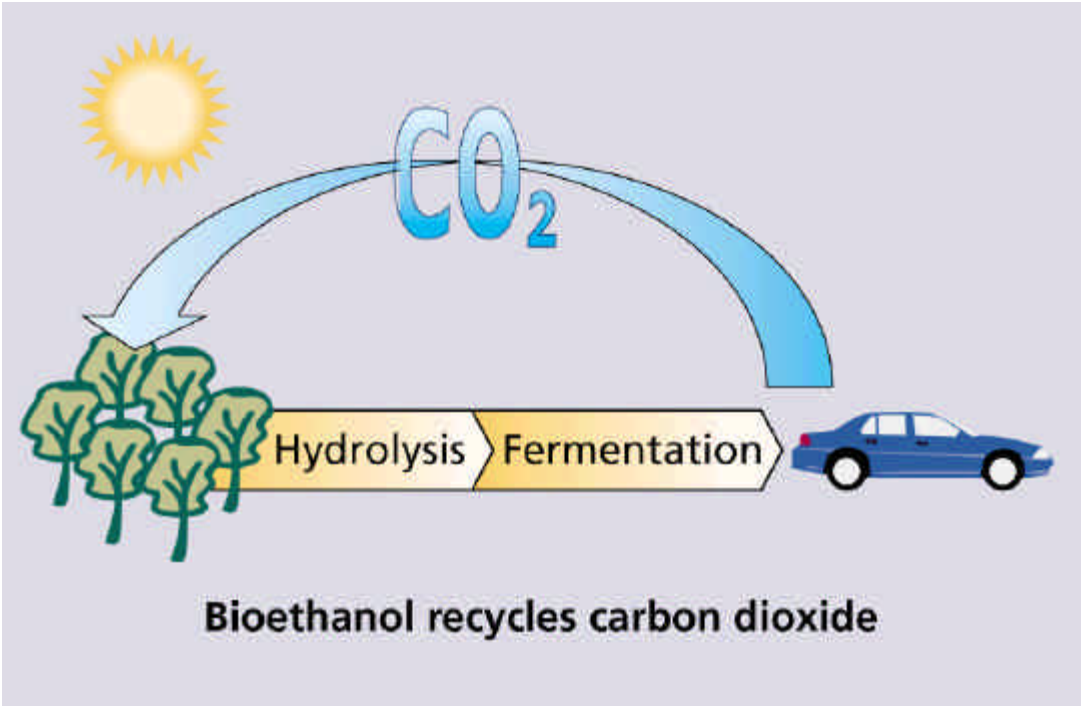
The Technology: today...



Everything that has been done or could be done to improve production of bioethanol from biomass can be categorized in terms of sugar production or fermentation

The Technology: today...

- 1st Generation Technology
  - Concentrated Sulfuric Acid
    - Masada
  - Two Stage Dilute Sulfuric Acid
    - BC International
  - Pioneer plants using “niche” feedstocks and new engineered organisms for cofermentation of C5 and C6 sugars
  - We anticipate that the first plants will be on line in 2003 to 2005 timeframe

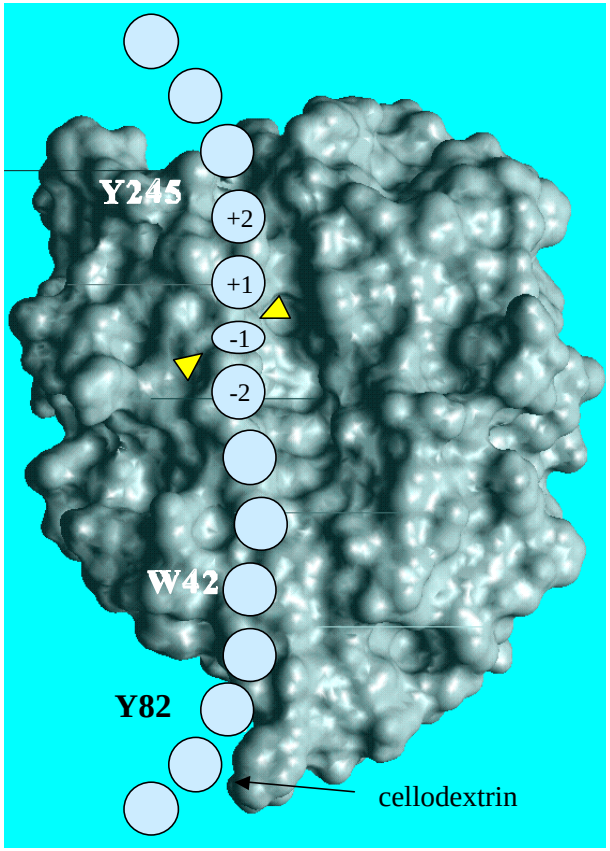
The Technology: tomorrow...

- 2nd Generation Technology
  - Enzymatic Hydrolysis.
  - By comparison, enzyme technology is not nearly as well developed as acid technology.
  - but enzymes offer greater opportunities for cost reduction in the long term

The Technology: tomorrow...

We are relying on the exploding advances in biotechnology to achieve the long term cost competitiveness of bioethanol

For many, the benefits of biotechnology must be carefully weighed against the environmental risks of genetically engineered organisms

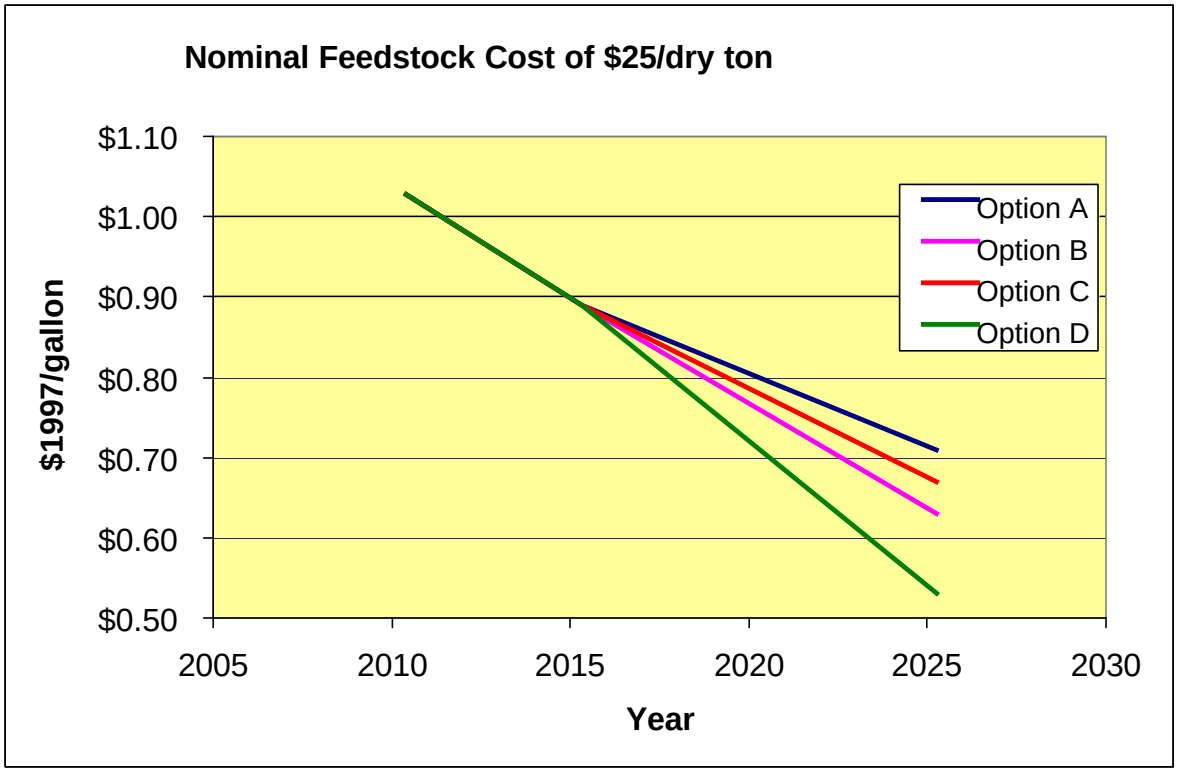


The Technology: Risks

- Market uncertainty

The Technology: Risks

- Technical uncertainty for new enzyme technology
- The rewards are great, but this is high risk research
- We need to be in the game for the long haul



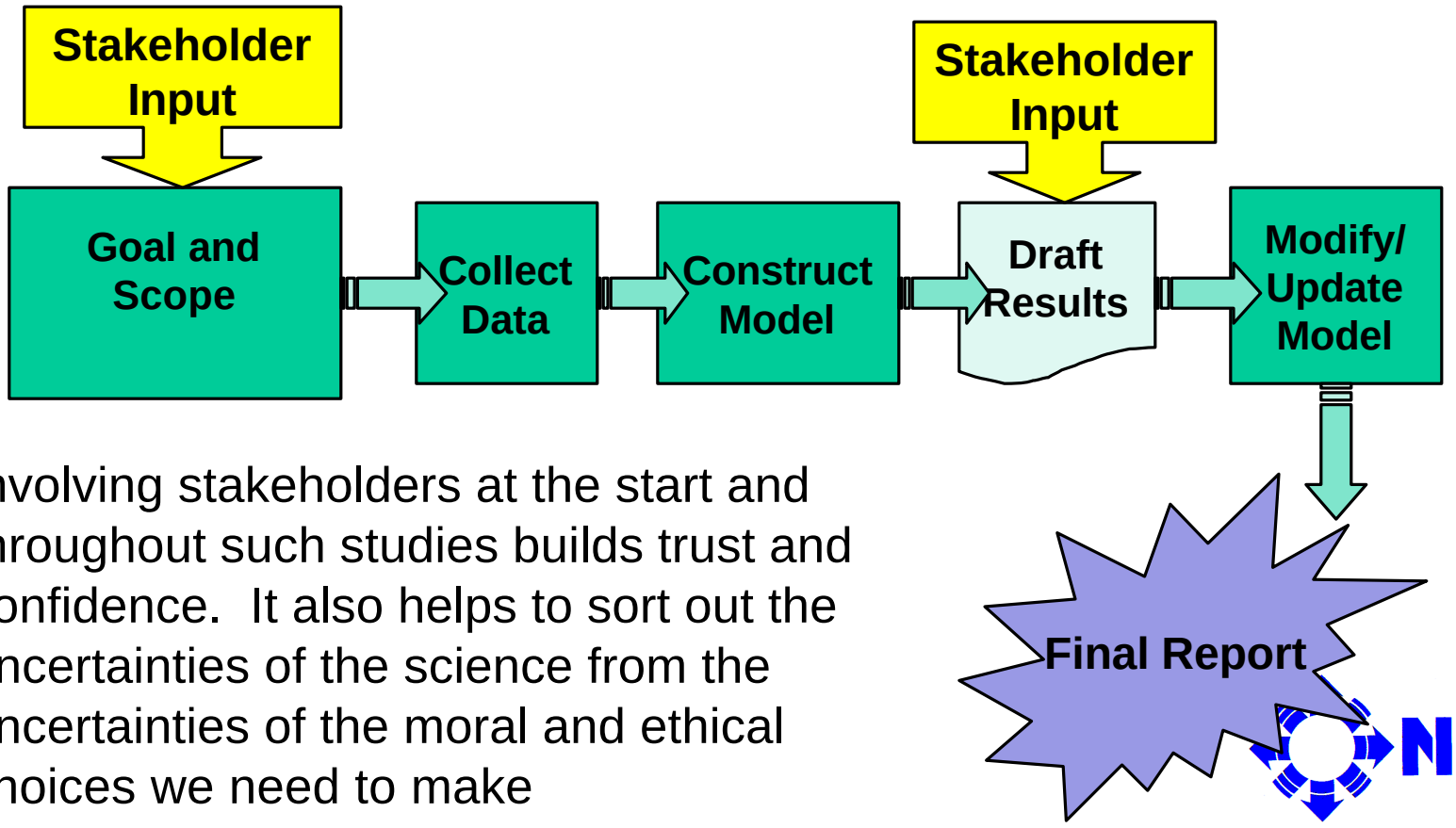
The Technology: The risks of using biomass

- New crops and new management practices always have some risk of "unintended consequences."
- We must continue to look at issues such as
  - Biodiversity
  - Natural Habitats
  - Soil health and sustainability

The Technology:
The risks of using biomass

- Our latest life cycle study considered the effects of collecting corn stover on the long term health of soil
- Preliminary findings show that—*when done responsibly*—residue collection can offset petroleum fossil CO2, reduce our dependence on petroleum and still allow carbon sequestration in soils

Life cycle analysis—a tool for dialogue



Involving stakeholders at the start and throughout such studies builds trust and confidence. It also helps to sort out the uncertainties of the science from the uncertainties of the moral and ethical choices we need to make

Bioethanol's future

- The next few years will see the first cellulose-to-ethanol plants since World War I
- Solving environmental problems like rice straw burning and using hitherto unvalued residues like corn stover represent a huge untapped resource for fuel production
- Using biotechnology responsibly, we can develop bioethanol technology that contributes to the overall sustainability of our transportation sector